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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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INVENTOR(S)

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Additional inventors are being named on the one (1) *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

HIGHLY INSULATED EXHAUST MANIFOLD

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS *(check all that apply)*

[X] Specification *Number of Pages* 24

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[ ] Application Data Sheet. See 37 CFR 1.76

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Respectfully submitted,

SIGNATURE [signature]

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REGISTRATION NO. 48719 *(if appropriate)*

Docket Number: 36452

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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PROVISIONAL APPLICATION COVER SHEET
Additional Page

Docket Number 36452

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First Named Inventor	Ajit Y. Sane
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FEE CALCULATION

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1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	80.00

SUBTOTAL (1) ($) 80.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		×		=	
Independent Claims		- 3** =		×		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($)

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,330	2453	665	Petition to revive - unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

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HIGHLY INSULATED EXHAUST MANIFOLD

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an exhaust manifold, and more particularly to a highly insulated exhaust manifold for an internal combustion engine in a motor vehicle.

Description of Related Art

Catalytic converters in motorized vehicles, particularly passenger automobiles, must reach a certain temperature before they "light off". Light off occurs when the catalytic converter begins to convert harmful pollutants by oxidizing carbon monoxide and hydrocarbons to CO_2, and reducing NO_x to N_2 and O_2. It is important to minimize the time to light off once a car is started to minimize the amount of harmful pollutants emitted to the atmosphere.

Catalytic converters typically are heated to light off by the high temperature engine exhaust gas itself. Unfortunately, the catalytic converter normally is mounted downstream of the exhaust manifold which conducts the heated exhaust gas from the engine. A typical exhaust manifold is made of metal, or substantially made of metal. Metal exhaust manifolds conduct and disperse thermal energy away from exhaust gas to the outside atmosphere. This loss in thermal energy reduces the exhaust gas temperature before it reaches the catalytic converter and delays light off.

Various techniques for insulating exhaust manifolds and/or for providing other means to speed up light off have been suggested and attempted. Cast iron exhaust manifolds are useful but heavy. Also, the mass (large thermal mass) of iron drains heat from the exhaust gas. Welded tubing exhaust manifolds have less mass, but are complicated and expensive. Double-walled welded tubing exhaust manifolds have been suggested, with an air gap between the walls, but the two walls have the same thickness and are both structural and such an exhaust manifold would be unreasonably complex to manufacture.

U.S. Patent No. 5,419,127 teaches an exhaust manifold having inner and outer metal walls enclosing a layer of insulating material. Because the inner layer is metal and defines the wall of the exhaust gas pathway (i.e. it contacts the traveling exhaust gas), it conducts heat from the traveling exhaust gas thus delaying light off. In addition, the metal inner layer is subject to erosion or loss of integrity over time from thermal cycling.

U.S. Patent Application Serial No. 10/008,828, Notice of Allowance mailed December 16, 2003, describes an insulated exhaust manifold having a ceramic inner layer and a ceramic insulation layer encased in a metallic outer structural layer. This arrangement has proven effective at substantially reducing the amount of heat conducted away from exhaust gases while traveling through the exhaust manifold on the way to the catalytic converter. For example, for exhaust gas whose initial engine-exit temperature is in the range of about 1800-2000°F, a manifold constructed as described above exhibits an outer surface temperature (outer surface of the metallic layer) of about 850-900°F. This is a substantial improvement over entirely metal exhaust manifolds, whose outer surface temperature for the same exhaust gas typically would range from 1300-1500°F. However, it is desirable to reduce even further the degree of heat conducted away from the exhaust gas in the exhaust manifold, such that the outer surface temperature of the manifold is even cooler; e.g. less than 600, 500 or 400°F, or lower. Such a low degree of heat conduction will translate into hotter exhaust gas on exiting the manifold, resulting in faster catalytic converter light off.

Accordingly, there is a need in the art for a highly insulated exhaust manifold that substantially reduces the amount of heat conducted or convected away from the exhaust gas, even compared to the ceramic insulated manifold described above.

SUMMARY OF THE INVENTION

An exhaust manifold is provided having a ceramic inner layer defining an exhaust gas passageway, a composite insulation zone disposed exterior to and adjacent the inner layer, and an outer structural layer disposed exterior to the composite insulation zone. The composite insulation zone includes at least one metallic foil layer.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top view of an exhaust manifold of the present invention for conducting exhaust gas away from one side of a typical V-6 engine.

Fig. 2 is a cross-sectional view taken along line 2-2 in Fig. 1, showing an embodiment of the manifold having an inner layer, a composite insulation zone, a strain isolation layer, and an outer structural layer.

Fig. 3 is a cross-sectional view as in Fig. 2, wherein the composite insulation zone is composed of alternating discrete metallic foil and ceramic layers, according to a preferred embodiment of the invention.

Fig. 4 is a cross-sectional view as in Fig. 2, wherein the composite insulation zone is

composed of a plurality of metallic foil layers, with adjacent ones of the foil layers enclosing and defining substantially evacuated annular spaces therebetween, according to a further preferred embodiment of the invention.

Fig. 4a is a longitudinal cross-section of the composite insulation zone of Fig. 4 shown apart from the manifold, showing the individual metallic foils joined together along the circumference of their respective terminal edges, thereby defining the annular spaces in between adjacent foils.

Fig. 5 is a cross-sectional view as in Fig. 2, wherein the composite insulation zone is composed of at least one pair of opposing metallic foil layers enclosing and defining an annular space therebetween, wherein the annular space is filled with substantially evacuated glass or ceramic microspheres according to a further preferred embodiment of the invention.

Fig. 6 is a cross-sectional view taken along line 6-6 in Fig. 1, showing an embodiment of the manifold having an inner layer, a composite insulation zone and an outer structural layer, where the composite insulation zone has been provided with a plurality of intumescent tabs in openings made at discrete locations through the layers of the composite insulation zone.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

In the description that follows, when a range such as 5 to 25 (or 5-25) is given, this means preferably at least 5 and, separately and independently, preferably not more than 25.

The term ceramic includes any inorganic compound, typically (though not necessary) crystalline, formed between a metallic (or semimetallic) and a nonmetallic element, and mixtures thereof; for example, alumina (Al_2O_3), titania (TiO_2), and boron nitride (BN), where Al and Ti are metallic elements, B is semimetallic, and O and N are both nonmetallic. Ceramics also include mixtures of ceramic compounds; i.e. soda-lime-silica glass is a ceramic composed of sodium oxide, calcium oxide and silicon oxide. As used herein, a ceramic (such as a ceramic layer, ceramic fibers or filler material, or any other ceramic component or material) can be and preferably is substantially ceramic; preferably comprising at least 80, preferably at least 85, preferably at least 90, preferably at least 92, preferably at least 94, preferably at least 96, preferably at least 98, wt.% ceramics as described in the preceding sentence, with the balance being additives and/or contaminants. Ceramics or ceramic materials include glasses, such as borosilicate glass, aluminosilicate glass, calcium aluminoborate glass, calcium aluminoborosilicate, and other known or conventional glass materials. Glasses are a special subclass of ceramic materials having an amorphous structure.

An exhaust manifold according to the invention has at least one inlet and at least one outlet. With reference to Fig. 1, an exhaust manifold 10 is shown having three inlets or runners 5, 6 and 7 and one collector or outlet tube 8. Preferably, runners 5, 6, and 7 have inlet flanges 14, 15 and 16 respectively for mounting to exhaust ports in the engine block, and outlet tube 8 preferably has an outlet flange 12 for mounting to the exhaust pipe of an exhaust system. The manifold pictured in Fig. 1 is configured to conduct exhaust gas away from one side of a typical V-6 internal combustion engine. Exhaust gas from each of three cylinders on one side of the engine (not shown) enters that cylinder's corresponding runner 5, 6 or 7 in the exhaust manifold and exits the manifold through outlet tube 8. The outer surfaces of the inlet flanges preferably define a plane of assembly for mounting the exhaust manifold 10 to the head of the internal combustion engine. The inlet flanges 14, 15, and 16, and outlet flange 12 are all preferably made from cast iron or steel.

It will be understood that an invented manifold can be configured having, for example, 2, 4, 6, or any number of runners to accommodate engines having different numbers of cylinders (e.g. 4, 8, 12, etc.) and different configurations (e.g. in-line instead of V-oriented cylinders).

Referring to Fig. 2, manifold 10 is composed of multiple layers. Preferably, all the runners and the outlet tube have the same multiple layer construction. The manifold 10 has at least the following layers: inner layer 22, composite insulation zone 24, and outer structural layer (or outer layer) 28. Optionally and preferably, manifold 10 also has a strain isolation layer 26 disposed between outer layer 28 and insulation zone 24. The compositions and physical characteristics of each of the above layers will now be described.

Inner layer 22 defines an exhaust gas passageway 20 preferably having a diameter of 1-3 inches. Inner layer 22 is a dense ceramic layer or glaze that provides a smooth, nonporous or substantially nonporous, thermally resistant inner surface 21 for contacting hot exhaust gas as it passes through the manifold 10. The inner layer 22 is preferably composed of non-fibrous thermal shock resistant and erosion resistant dense ceramic, less preferably of ceramic fibers and a non-fibrous ceramic filler material. It is preferred that the non-fibrous dense ceramic is chosen from one or more of phases belonging to ceramic multi-component systems comprising alumina-silica-calcia-magnesia-titania. While oxide materials are usually cheaper to fabricate, it is also possible to consider a combination of non-oxide or oxide and non-oxide systems such as Si_3N_4, SiC, Si/SiC, Si/Si_3N_4 (e.g., the notation Si/SiC means silicon bonded SiC) and SiC-Si_3N_4-Al_2O_3-Y_2O_3. The primary selection criterion is the

thermal shock resistance under cyclic conditions when the engine is quickly turned to full power after it is allowed to be at ambient temperature. In the case of fibrous materials, the ceramic filler material preferably fills the void or interstitial space between the fibers, and preferably coats the fibers. The ceramic fibers are preferably aluminosilicate fibers, less preferably silica fibers, less preferably alumina (such as Saffil from DuPont) or zirconia fibers, less preferably alumina-borosilicate fibers (such as Nextel from 3M), less preferably a mixture thereof. The above ranking of ceramic fibers is largely based on material cost and/or shrinkage under operating and processing conditions. Aluminosilicate fibers are presently the most widely available ceramic fibers (they are less expensive than alumina or zirconia), that are suitable to withstand the temperature ranges for many exhaust manifolds, typically 1600-1800°F). Any of the above fibers will perform adequately for most exhausts having a temperature of about 1600-1800°F (i.e. automobile exhausts). Silica can withstand exhaust temperatures up to about 2100°F, while the more expensive alumina and zirconia fibers can withstand exhaust temperatures up to 2300°F and beyond. These more expensive fibers should only be used when required to withstand such high-temperature exhausts over a sustained time interval.

The ceramic filler material in inner layer 22 is selected to be stable or substantially stable against oxidation in strong oxidizing environments up to 1600, 1800, 2000, 2100, or 2300, °F, or greater, as the application requires. Material preference can be based on factors other than but not excluding performance. Such additional factors may include cost, ease of fabrication or incorporation into a particular manufacturing scheme, and thermo-mechanical compatibility with other constituents. Preferred ceramic filler materials suitable to withstand oxidation up to 2100°F are alumina, mullite (aluminosilicate), silica, other metal oxides (e.g. titania, magnesia, or ceria), partially stabilized zirconia (PSZ), silicon carbide, silicon nitride, aluminum nitride, silicon boride, molybdenum disilicide, as well as borides, carbides, nitrides and oxides of refractory metals, and mixtures thereof. Included in these materials is a glass or glass-ceramic frit constituent of some of these components: alumina, silica, B_2O_3, P_2O_5, TiO_2 and an alkaline earth oxide such as MgO, CaO or a mixture thereof. Less preferably, the ceramic filler material can be an alkaline oxide or transition metal oxide. Alkaline oxides and transition metal oxides may provide similar performance to alumina or silica filler materials in inner layer 22. Less preferably, the ceramic filler material in inner layer 22 is SiC, SiB_4, Si_3N_4, or a mixture thereof. Such materials are even less preferred when the ceramic filler material in inner layer 22, particularly non-fibrous and crystalline ceramic, is in

the sintered form. Less preferably, the ceramic filler material can be those glasses that may cause unacceptable dimensional changes in ceramic fibers, for example, when used in conjunction with silica or high silica fibers: glasses such as alkali containing calcium borosilicate glass, aluminosilicate glass, calcium aluminoborate glass, less preferably any other glass material capable of withstanding exhaust temperatures of 1200, preferably 1400, preferably 1600, preferably 1800, preferably 2100,°F. Less preferably, ceramic filler material in inner layer 22 can be any other highly refractive ceramic material known in the art. The ceramic filler material preferably is provided as a ceramic powder (preferably colloidal when used as an inorganic binder) which, once it is fired, preferably forms into and fills the spaces between, preferably coating, the ceramic fibers. The ceramic fibers can be short fibers, long fibers, or a mixture thereof. Preferably, short fibers have a length of about 10-1000, preferably 20-100, µm, and long fibers have a length greater than 10,000 µm (10 mm). Both long and short fibers preferably have a diameter of 0.1-20, preferably 0.15-10, preferably 0.2-5, µm. Inner layer 22 is preferably 40-98, preferably 50-96, preferably 60-94, preferably 70-92, preferably 75-90, wt.% ceramic filler material, balance ceramic fibers. Inner layer 22 preferably has a porosity less than 20%, preferably less than 15%, preferably less than about 10%, with the localized porosity at the inner surface 21 of inner layer 22 being near zero or substantially zero, preferably less than 5, preferably less than 3, preferably less than 1, percent. It is important to have a very low (near zero) localized porosity at the inner surface 21 in order to provide a gas-tight or substantially gas-tight exhaust passageway 20, and further to provide a highly smooth surface to minimize frictional losses and pressure drop across the manifold 10. Preferably, inner layer 22 has a thickness of 0.05-8, preferably 0.08-3, preferably 0.1-2, mm. In the case of non-fibrous composition, inner layer 22 has a thickness of 0.05-10 mm, preferably 0.1-8 mm, preferably 1-6 mm.

The inner layer has low thermal conductivity and thermal diffusivity compared to metal. In addition, it is backed up by a highly insulating zone 24 as shown in Fig. 2 and described below. Consequently, the passing exhaust gas in passageway 20 retains a much greater proportion of its thermal energy rather than conducting/convecting it to the outer layers as heat.

In a preferred embodiment of the invention, illustrated in Fig. 3, the composite insulation zone 24 is a multi-layer zone composed of alternating layers of thin metallic foils 31 having ceramic insulating layers 32 disposed between adjacent ones of the foils 31. The foils 31 preferably are made from a highly reflecting or low emissivity metal or metal alloy,

most preferably aluminum. By "highly reflecting," it is meant that majority of infra-red radiation is reflected and not transmitted. The most preferred case is 100% reflectance of infra-red radiation and 0% transmission or absorption. The next most preferred is at least 80% reflectance. By "low emissivity," it is meant that emissivity is less than 0.5 and preferably less than 0.3. According to published literature, polished aluminum typically has emissivity in the range of 0.1 to 0.2 even if it is oxidized at1100°F. [Ref: Transport Phenomena in Metallurgy by G.H. Geiger and D.R. Poirier Addison-Wesley Publishing Co. 1973]. The presence of the foils 31 facilitates a substantial reduction in radiative heat transfer. The use of multiple foils 31 in the composite insulation zone 24 assures their effectiveness in the case of degradation of their properties under excessive heat, specifically for those foils at a temperature above 1100°F. The metallic foils preferably are 0.005-0.2 mm, preferably 0.01-0.1, preferably about 0.02-0.05, mm thick. Though it is preferred (for simplicity) that all the metallic foils 31 in the insulation zone 24 are made from the same material and have the same thickness, it is contemplated that different metallic foils 31 can be made from different metals or have different thicknesses. For example, based on the reflectance and/or emissivity properties of different metals, one may select combinations of foils 31 to provide an insulating zone 24 having insulating properties that are particularly suited or adapted to a specific application, exhaust gas temperature, or desired outer surface manifold temperature. Foils 31 closer to the inner layer 22 may be selected from high temperature oxidation resistant alloys such as polished nickel or cobalt alloys, while foils closer to outer layer 28 may be aluminum or aluminum alloys. Determination and selection of further combinations of metallic foils 31 as described herein can be made for a specific application by persons of ordinary skill in the art without undue experimentation.

The ceramic insulating layers 32 in the composite insulation zone 24 preferably are composed of ceramic fibers and/or non-fibrous (preferably colloidal) ceramic filler material similarly to the inner layer 22. The ceramic fibers and filler material used in the ceramic insulating layers 32 can be the same materials as inner layer 22, except for a given insulating layer 32 they are combined in different ratios compared to the inner layer 22. In the insulation layers 32, fibers make up 65-99, preferably 70-96, preferably 75-94, preferably 80-92, preferably 85-90, wt.% of the layer, with the balance being ceramic filler material. Alternatively, the ceramic insulating layers 32 can be provided having substantially 100% ceramic fibers with no or substantially no filler material.

Preferably, the ceramic fibers in each of the insulating layers 32 are silica fibers,

alumina fibers, or aluminosilicate (or boroaluminosilicate) fibers of sufficiently high alumina content, preferably 40-99, more preferably 50-90, more preferably 55-80, most preferably 60-75, wt.% alumina. High alumina content in the insulating layers 32 enables the composite insulation zone 24 to resist shrinkage at high temperature. Alternatively, high purity silica fibers may be used if the manifold 10 is to be used with lower temperature exhaust such that the resulting shrinkage of insulation zone 24 will not be greater than 0.5%. The insulating layers 32 preferably have a porosity of 20-95, preferably 40-90, preferably 60-90, preferably 70-90, preferably about 75-85, percent. This high porosity is achieved by increasing the ratio of ceramic fibers to filler material as compared to inner layer 22.

It is possible to use ceramic filler material having a high level of microporosity, thereby increasing the thermal resistance, and consequent insulation capacity, of the layers 32. For example, silica in the form of silica aerogel particles, can be used to fill interfiber spaces to improve insulating characteristics of the layer. The composite insulation zone 24 preferably has an overall thickness of 1-40, preferably 2-30, preferably 2-20, mm, including all of the metallic foil 31 and ceramic insulating layers 32 therein.

The ceramic insulating layers 32 preferably are rigidized to promote dimensional stability and erosion resistance. Rigidization is preferably achieved with one of the following rigidizers: colloidal silica or silica precursor, colloidal alumina or alumina precursor, finely divided glass frit, or a mixture thereof. Where one of the above (or another) rigidizer is used as the ceramic filler material in a layer 32, no additional rigidizer is required. Where a non-rigidizer is used as the ceramic filler material in a layer 32, that layer preferably also contains 1-15, preferably 3-12, preferably 4-10, preferably 5-8, preferably about 6, wt.% rigidizer. In a further preferred embodiment, illustrated in Fig. 4, each pair of metallic foils 31 in the insulation zone 24 encloses and defines a substantially evacuated annular space 35 between the adjacent foils. As seen in the figure, adjacent pairs of foil layers can share a foil layer in common, e.g., yielding the illustrated construction:

foil : evacuated space : foil : evacuated space : foil

In this embodiment, spacers 36 may be provided to maintain the separation of adjacent metallic foil layers and the integrity of the respective evacuated annular spaces 35. Cylindrical sections of the insulation zone 24 can be made according to this embodiment by joining cylindrical metallic foils 31 around the circumference of their respective terminal edges as shown in Fig. 4a, and then evacuating the thus-defined annular spaces between the foils via known or conventional techniques. The foils can be joined, e.g., by brazing or

welding their terminal circumferential portions 42 together to create a circumferential weld-seam between the foils that is substantially air-tight and effective to maintain a vacuum in the annular spaces 35. Each space 35 preferably is filled with insulating ceramic material selected from those materials described for the inner layer 22. In addition, the spaces 35 may also be filled with loose ceramic powder (the term "loose" means no binder is provided, the powder particles are uncohered) with low intrinsic thermal conductivity such as aerogel particle of silica, fumed silica, stabilized and expanded vermiculite having fine pores, etc.

Fig. 5 illustrates a further preferred embodiment of the invention, in which a microsphere layer 37 is disposed between adjacent metallic foil 31 layers. Each pair of opposing metallic foil 31 layers defines an annular space 35a between the foils. The annular space is filled with substantially evacuated hollow glass or ceramic microspheres to provide the highly evacuated microsphere layer 37 in between adjacent metallic foils 31 in the composite insulation zone 24. As discussed below, the use of evacuated microspeheres makes it easier to provide substantially evacuated spaces in the composite insulation zone 24 without having to evacuate annular spaces between metallic foil 31 layers. Such an arrangement allows effective thermal conductivity of the microsphere layer 37 to be less than that of a stagnant air layer of equivalent dimensions. Such a layer of stagnant air has been reported to have thermal conductivity of about 0.02 BTU/hr-ft-°F. Preferably, the microspheres are in the range of 10-1000, preferably 100-500 (+/-10%) microns in diameter having a composition substantially belonging to the system of Al_2O_3-SiO_2-Alkaline Earth Oxide (CaO, MgO, etc) including fused silica with a softening point greater than 2000°F and preferably 2500°F. Suitable microspeheres are commercially available from Hy-Tech Thermal Solutions, L.L.C., Melbourne, Florida, USA. The microspheres in the microsphere layer 37 can be, and preferably are, loosely packed in the annular space 35a between adjacent foils 31. By loosely packed, it is meant that the microspheres essentially are poured or injected into the annular space 35a sufficient to fill the space between the foils, but are not adhesively bound to one another or to the foils 31, e.g. using any sort of binder. Loosely packed does not necessarily mean that the microspheres are not packed tightly or crammed in the annular space 35a (they can be), only that no adhesive or binder is used to cohere them. Less preferably, the microsphere layer 37 can include a binder, such as a ceramic binder material, effective to provide a cohesive microsphere layer 37 in the annular space 35a. Use of a binder is less preferred because the binder itself may reduce flowability of microspheres. Preferably, to ensure maximum evacuated volume, microspheres are packed as tightly as

possible into the annular space 35a to provide the microsphere layer 37.

The evacuated annular space 35 described above and illustrated in Fig. 4 has better insulating properties than the microsphere layer 37 described in the preceding paragraph because the evacuated annular space 35 has a lower thermal mass than the microsphere layer 37. However, the microsphere layer 37 may be preferred because it is easier to make and provide in the manifold 10 from a manufacturing standpoint; i.e. it is not required to join the metallic foils 31 circumferentially at their terminal edges because the microsphere layer 37 does not depend on a hermetic air tight seal. Instead, the microsphere layer 37 effectively approximates an evacuated space or layer because the internal volumes of the microspheres themselves are evacuated or at substantially reduced pressure as a result of the process by which they are manufactured. Thus, a substantial proportion of the volume of the microsphere layer 37 is evacuated or maintained at substantially reduced pressure. Further, while the microsphere walls themselves are solid, they are made from ceramic material and consequently are poor conductors of heat.

It is to be noted the composite insulation zone 24 can be or comprise a combination of any or all of the above-described layers having insulating properties, in alternating arrangement with the metallic foils 31. For example, the composite insulation zone 24 can include a ceramic insulating layer 32, a microsphere layer 37, an evacuated annular space 35, or any combination of these, in alternating arrangement with and separated by metallic foils 31. Appropriate combinations of these layers in the composite insulation zone 24 can be determined and selected by a person of ordinary skill in the art without undue experimentation based on a particular application.

The composite insulation zone 24 according to the invention is effective to insulate the exhaust gas traveling through passageway 20 adjacent inner layer 22 such that the gas retains at least 80 preferably 85, preferably 90, preferably 95, percent of its initial thermal energy (or temperature) on exiting the manifold 10.

The strain isolation layer 26 is an optional layer, and preferably is disposed exterior to and adjacent, preferably in direct contact with, the outer wall surface of composite insulation zone 24. Strain isolation layer 26 is disposed between the composite insulation zone 24 and the outer layer 28. Strain isolation layer 26 is a very thin layer, preferably 0.05-3, more preferably 0.1-2, mm thick, and is preferably made of ceramic fibers and/or ceramic filler material. Preferably, strain isolation layer 26 is composed of the same or similar ceramic fibers as the inner layer 22. However, the ceramic filler material in isolation layer 26 is

chosen to be metal resistant; i.e. to resist seepage of molten metal during application or casting of outer structural layer 28 which is preferably a metal layer as will be described. The preferred metal resistant ceramic filler material in strain isolation layer 26 depends on the metal used for outer layer 28. If outer layer 28 is a ferrous metal layer (i.e. steel), then zirconia, alumina, boron nitride, zircon (zirconium silicate $ZrSiO_4$), or a mixture thereof is the preferred ceramic filler material for layer 26. If aluminum or an aluminum alloy is used for outer layer 28, then the preferred ceramic filler material for isolation layer 26 is alumina, boron nitride, calcium aluminoborate glass, calcium aluminoborosilicate, calcium aluminate cement or a mixture thereof. When boron nitride is used (preferably with a ferrous metal outer layer 28), the boron nitride is preferably applied via spray coating, dipping, or other similar means. Boron nitride is preferably applied as a slurry of boron nitride and a liquid such as water, preferably having ceramic fibers as described above dispersed therein. Strain isolation layer 26 preferably has 70-99, preferably 80-90, wt.% ceramic fibers, balance filler material. When boron nitride, zircon, alumina and mixtures containing them are used for the isolation layer, ceramic fibers may not be required but are preferred. Layer 26 is a compliant layer and is not rigidized.

Alternatively and preferably, the strain isolation layer is an intumescent mat. The intumescent mat is composed of ceramic fibers, an expandable material, and a binder material, wherein the basic construction is that of a highly porous, compliant, resilient, and spongy fibrous mat. The binder is present in an amount effective to bind the ceramic fibers and the expandable material together in the mat construction to provide a coherent fibrous mat. Suitable binder materials include organic binders such as methyl cellulose ether, less preferably starch, less preferably polyvinyl acetate or polyvinyl butyrol, less preferably another known organic binder, less preferably a mixture thereof. Less preferably the binder can be a mixture of organic and inorganic binders. The expandable material preferably is in the form of embedded particles of vermiculite, perlite, or combinations thereof, which are dispersed throughout the fibrous mat. Vermiculite is a naturally occurring mineral, a member of the phyllosilicate group. Perlite is a naturally occurring siliceous rock or volcanic glass. The distinguishing characteristic of each of these materials is that each exhibits the unique property of expanding many (i.e. 4-20) times on heating. Preferably, the fibrous mat has the following composition by weight: 20-60, preferably 25-50, preferably 30-45 weight percent ceramic fibers, 35-75, preferably 40-65, preferably 45-60 weight percent vermiculite or perlite (or combination) particles, balance ceramic filler or binder material. The binder has

the effect of constraining the fibers in their resting orientation or state, resulting in the intumescent mat being resilient (or rebounding) following external compression or expansion of the mat. Conversely, the vermiculite particles expand in volume on being heated, and the expansion of the dispersed vermiculite particles tends to cause the intumescent mat to expand on heating. The result of these competing effects is a compliant, resilient intumescent mat that expands on heating, and contracts or rebounds substantially back to its initial state (unexpanded or substantially unexpanded) on cooling. The expanding/rebounding property of the intumescent mat will be maintained so long as the mat is not heated above the temperature at which the binder is baked off. Once this temperature (referred to as the crossover temperature) has been reached, the binder is depleted from the mat and the force tending to constrain the expansion of the ceramic fibers is removed. Therefore, above the crossover temperature the intumescent mat irreversibly expands from the heat-induced expansion of the dispersed vermiculite (or perlite) particles; on cooling the mat will no longer contract or rebound to its initial state because the contracting/binding influence of the binder material has been removed. Therefore, it will be understood that once the intumescent mat has been cycled once above the crossover temperature, it will no longer rebound from an expanded state.

On the other hand, if the crossover temperature is likely to be exceeded (e.g. during operation of the manifold 10) then the thickness of the intumescent mat should be adjusted so that after binder burn-off and consequent expansion of the vermiculite, the inner layer 22 is subjected to a modest compression so that it will not be damaged. Under these conditions, if the metallic outer layer 28 expands relative to ceramic inner layer 22, expansion of the intumescent mat is accommodated by the expanded outer layer 28 resulting in reduced compression at the inner layer 22. It is very important to select the temperature (the reference temperature) at which the metallic outer layer 28 and the ceramic inner layer 22 are assembled, and their relative expansion coefficients. By judicious selection of materials and adjusting effective expansion coefficients, thermal mismatch can be reduced. For example, a cast manifold undergoes a large temperature excursion during fabrication (as determined by the melting point of the metal) and hence there is a greater likelihood of expansion/contraction mismatch once the cast outer layer 28 cools. On the other hand, if the outer layer 28 is provided as an assembly of two split-molded or clamshell molded halves assembled around the inner layers at or near room temperature, the outer layer 28 is less likely to exhibit so great a thermal mismatch with the inner layer 22.

For example, aluminum is cast at a temperature in the range of 600-650°C, while its temperature during use as the outer layer in a manifold according to the invention would be much less, e.g. 200-300°C. Therefore, for a manifold whose metal outer layer 28 is assembled at room temperature, the outer layer 28 is likely to be expanding by 200-300°C (operating temperature for the outer layer 28); whereas for a cast metallic outer layer 28, the outer layer would not exhibit any substantial thermal expansion below the casting temperature of 600-650°C, which it will not reach due to the highly insulative properties of the composite insulation zone 24.

Therefore, when an intumescent mat is used for the strain isolation layer 26, its expansion-contraction properties and its thickness relative to (a) the gap between the concentric outer layer 28 and the insulation zone 24 and (b) the anticipated thermal excursions due to the fabrication process for the outer layer and the manifold operating conditions, should be taken into account in intumescent material selection.

The intumescent (expansion-contraction) property of the intumescent mat is advantageous in the present invention because as the manifold heats up or cools down with respect to a reference temperature determined by the fabrication process, expansion of the metallic outer layer 28 and the various ceramic inner layers (22 and 32) can be mismatched such that they occur at different rates. The intumescent mat allows for and accommodates relatively large changes in the relative displacement of these layers by providing reversible expansion-contraction characteristics over a large fraction of the mat's original thickness. For example, a 2 mm thick intumescent mat layer 26 that exhibits a 50% reversible change in displacement on heating/cooling can fill the space between the outer layer 28 and insulation zone 24, and provide effective support even if the spacing between the layer 28 and zone 24 varies from 1 to 3 mm due to thermal mismatch.

Strain isolation layer 26 absorbs or dampens vibrational stresses from the engine and from road harshness. Layer 26 also accommodates the unmatched thermal expansion characteristics of outer layer 28 and insulation zone 24. Because layer 28 is preferably made of metal, and in preferred embodiments the insulation zone 24 includes ceramic layers 32, the outer layer 28 has a much higher coefficient of thermal expansion than insulation zone 24 (typically about or at least twice as high). Consequently, the expansion and contraction of outer layer 28 (due to thermal cycling) likely would cause the ceramic layers in the composite insulation zone 24 to fracture in the absence of a compliant strain isolation layer 26. Even when ceramic insulating layers 32 are not used, the strain isolation layer 26 still prevents or

minimizes mechanical stresses from the outer layer 28 from being transferred ultimately to the ceramic inner layer 22 which may be damaged or crack under mechanical stress.

In the absence of a strain isolation layer 26, intumescent tabs 38 can be provided in openings 44 made at discrete locations through the layers of the composite insulation zone 24 (see Fig. 6) in order to stabilize the inner layer 22 relative to the outer layer 28 through thermal cycling of the exhaust manifold 10. In addition, if a strain isolation layer 26 is absent, the intumescent tabs 38 dampen mechanical vibrations or stresses between the outer layer 28 and the inner layer 22. Such damping is important to ensure the inner layer 22 of the manifold is not damaged or cracked from mechanical stresses as described in the preceding paragraph. The intumescent tabs 38 can be made or cut from the same material as the intumescent mat previously described.

As indicated above, outer layer 28 is a structural layer and preferably is made from metal. Preferably, layer 28 is a metal-containing layer or a metal composite layer. Metal-containing materials and metal composites are generally known in the art. Preferably, a metal composite layer contains ceramic filler material such as SiC, alumina, or a mixture thereof. Outer layer 28 preferably is disposed exterior to and adjacent the strain isolation layer 26 if present. In the absence of a strain isolation layer, outer layer 28 is disposed exterior to and adjacent the insulation zone 24. An outer metal layer provides mechanical and impact strength, and ensures gas-tightness of the invented exhaust manifold. Preferably, outer layer 28 is made of a ferrous metal, preferably cast ferrous metal or metal alloy such as steel. Less preferably, outer layer 28 is made from aluminum, less preferably any other suitable metal or metal alloy known in the art. Aluminum conserves weight, but may be subjected to creeping under stress from an applied load. This is why a ferrous metal (such as steel) outer layer 28 is preferred. However, aluminum can be used if steps are taken to avoid excess loading of the manifold to maintain stresses below the creep threshold, i.e. with brackets to support the manifold. Preferably, the outer layer 28 is 1-25, preferably 2-20, preferably 5-15, mm thick.

The exhaust manifold according to the invention, having a ceramic inner layer 22, a composite insulation zone 24, strain isolation layer 26 a metal outer layer 28, preferably is made as follows. The inner layer 22 is made first by slip casting the inner layer 22 in the appropriate configuration for the desired manifold; i.e. having the appropriate piping configuration, number and placement of runners, etc. Slip casting techniques are very well known in the art and will not be described further here, except to describe the preferred slip casting composition. The slip casting composition, also called "slip" preferred for use in the

present invention is a fused silica based slip composition. Such a fused silica slip composition is available from Industrial Ceramic Products, Marysville, Ohio. The slip composition is used to produce the layer 22 such that after firing, it is resistant to thermal shock, dimensional changes at elevated temperatures and resistant to high velocity gases.

The metallic outer layer 28 is prepared as two clamshell halves that can be suitably joined, e.g. along mating perimeter flanges 40 provided on each of the outer layer clamshells. Alternatively, the clamshells can be suitably joined by welding as known in the art. Prior to joining the outer layer clamshells, the strain isolation layer 26 (if present), composite insulation zone 24 and previously slip cast inner layer 22 are prepared and assembled together in the appropriate order, and placed within the volume of one of the clamshell halves such that the other clamshell half of the outer layer 28 can be fit thereover, enclosing all the constituent layers to form the manifold 10. Then the clamshell halves are suitably joined by a conventional technique to provide the finished exhaust manifold 10. Alternatively, if a metal seepage-resistant strain isolation layer is used, the inner layer 22, insulation zone 24 and strain isolation layer 26 can be constructed and assembled, and then used as a mold core for casting the outer metal layer 28 directly thereto.

To make the composite insulation zone, at least one metallic foil 31 is coated on one of its surfaces with ceramic fibers, hollow micro-spheres, ceramic binder, ceramic particulates etc., depending on the desired embodiment for the insulation zone 24 as described above. For ceramic insulating layers 32, the coating can be provided as an appropriate slurry having the desired combination or ratio of fibers to filler material as described above. Such ceramic slurries are well known in the art, and typically contain from 1 to 2 percent by weight solids, balance water. A second metallic foil is then provided over the coating on the first foil surface to provide a sandwich composite. This composite is then folded to conform to the proper shape and contour within the outer layer 28 clamshell half, between the inner layer 22 and strain isolation layer 26 (if present) prior to fitting the second outer layer 28 clamshell half to complete the manifold. Additional layers of foil/ceramic can be provided if it is desired to provide a composite insulation zone 24 having multiple ceramic insulation layers 32. Once the manifold is assembled, it is heated to bake off the water from the ceramic slurries and cure the ceramic insulating layers 32. If evacuated annular spaces 35 are to be used, the metallic foils are formed into concentric cylindrical forms and their terminal circumferential edges are joined as described above and illustrated in Fig. 4a, around the inner layer 22. For simplicity of construction in this embodiment, the composite

insulation zone can be made in a plurality of discrete sections which are separately and adjacently fitted around the slip cast inner layer 22. If a microsphere layer 37 is to be used, then adjacent metallic foils 31 first are assembled to provide the composite insulation zone 24, and then microspheres preferably are injected into the intermediate annular space 35a between adjacent metallic foils.

In a further embodiment, a catalyst belonging to a family of inorganic compounds, ABO_x with O being oxygen, is added to the inner surface 21 of the inner layer 22. Preferably the catalyst has either a perovskite structure (with A being a rare earth element and an alkaline earth element, and B being a transition metal element), or a fluorite structure (with A being a rare earth element and B being Ce or Zr). For a perovskite catalyst, A is preferably La and Sr, and B is preferably Fe, Co or Mn, less preferably Ti, Ga, Cr, or Ni. For a fluorite catalyst, A is preferably a rare earth metal such as Gd or Y and less preferably alkaline earth metal such as Ca or Mg. In addition, other known catalysts, such as partially substituted $BiMoO_3$ and Gd-doped CeO_2 can be used. Such a catalyst preferably is activated at a lower temperature than the platinum and palladium catalysts typical of most catalytic converters, and can begin to convert CO and NO_x to CO_2 and N_2 and O_2 during the period prior to light off after a vehicle is started. The catalyst preferably is provided as finely divided (preferably colloidal) particles, and can be added to the inner layer slip prior to slip casting thereof. Preferably, the catalyst particles are 0.1-5, preferably 0.5-4, preferably 1-3, wt.% of the total solids in the inner layer slip.

An exhaust manifold according to the invention has at least the following advantages. Faster light off of the catalytic converter will occur because the exhaust gas retains a greater proportion of its initial thermal energy on entry into the catalytic converter. Also, because heat loss to the exhaust manifold is significantly reduced, lighter metal such as aluminum can be used in the manifold provided operational stresses to the manifold are minimized as described above. The need for heat shields may also be reduced or eliminated. Further, manifolds disclosed herein resist erosion and corrosion because the ceramic inner layer 22 effectively resists these effects.

Additional information, including an experiment and test data, is provided in the attached pages following the ABSTRACT OF THE DISCLOSURE.

Although the hereinabove described embodiments of the invention constitute the preferred embodiments, it should be understood that modifications can be made thereto without departing from the scope of the invention as set forth in the appended claims.

Title of the invention: A highly Insulating Exhaust Manifold & Method

Keywords: Multi-Layered Insulation, Automotive Exhaust Manifold, Ceramic Manifold

Description of the invention: A novel exhaust manifold and a process for producing the same have been discovered for internal combustion engines. Its superior insulating qualities allow operation under severe operating conditions such that outer shell of the manifold is maintained at a temperature that is substantially lower than the temperature obtained in a conventional cast iron manifold.

A manifold is constructed out of a split metallic shell that acts as a clam shell (#3 in the following drawings) around a highly insulating core. In a preferred embodiment, a thermal shock resistant, erosion resistant slip-cast ceramic body (#1 in the following drawings) is used to define an internal exhaust gas passageway. This ceramic is surrounded by a multi-layer body (#2 in the following drawings) of thin highly reflecting or low emissivity metallic foils separated by thin insulating layers of ceramic coating. This coating may contain one or more of the following materials: ceramic fibers, hollow micro-spheres, ceramic binder, ceramic particulates etc. Preferably the metal foil is made out of aluminum that is coated with a suitable ceramic insulating layer. These foils are then molded into a shape that occupies space between the slip cast ceramic body and outer metallic clam-shell. In another method, the metallic foil is formed inside each of the metallic clam shell and coated with a thin ceramic coating and the process is repeated until a multi-layer insulating zone is obtained to fill the space between the slip cast ceramic core and the outer metallic clam-shell. Small tabs of expandable gasket such as intumescent mat are used to keep slip cast core in position during thermal cycling. Also, in another embodiment, a part of multi-layer metal/ceramic sandwich is replaced by ceramic micro-spheres or ceramic fibers that can be injected into the space between slip cast ceramic core and adjacent insulating layers.
(See drawings in the Appendix)

Specific Example:

A slip cast disc of fused silica refractory was fabricated by pouring a ceramic slip on a Plaster of Paris mold (ICP formulation #ICP-3, obtained from ICP, Ohio) and drying. After drying it was fired in a ceramic kiln. A multi-layer sandwich (A) was prepared by laminating layers of aluminum foil and ceramic paper. Another sandwich (B) was prepared by laminating layers of aluminum foil coated with thin layer of Zyalite paste (Vesuvius). Sample 1 & 2 were prepared by combining the slip cast disc with A and B respectively. The samples were tested in a set up designed to measure high temperature thermal resistance. The results are given in Table 1.

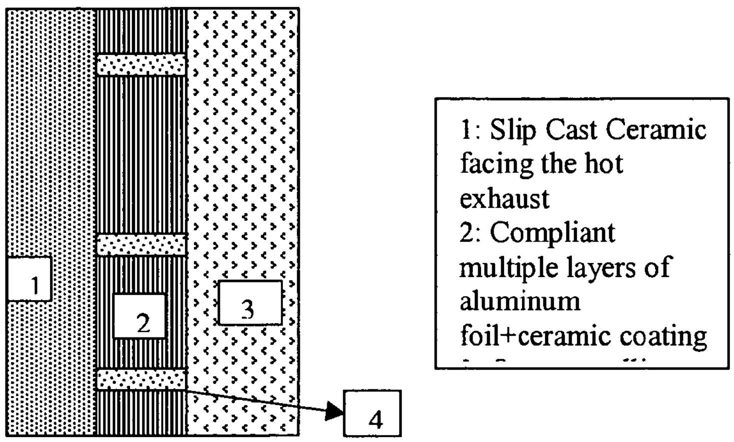
	Sample 1	Sample 2	Sample 3	Reference
Slip Cast ICP-3 thickness	0.265"	0.265"	0.265"	0.265
Laminate Thickness	0.105"	0.120"	0.120"	None
Laminate Type	Aluminum/Ceramic Paper	Aluminum/Zyalite	Aluminum/Zyalite	None
Hot Face Temp. of ICP (F)	1875	#1. 1856 #2. 1882	1906	1851
Cold Face of 0.187" Cold Rolled Steel (F)	340	#1: 325 #2: 384	212	878
Ambient Air	71F, 20% RH Air Speed -0	71F, 20% RH Air Speed -0	72F, RH=20% Air Speed 8.9 MPH	71F, 20% RH Air Speed -0
Comments	Cold Rolled Steel simulates metallic clam-shell	Cold Rolled Steel simulates metallic clam-shell	Cold Rolled Steel simulates metallic clam-shell	

The use of a multi-layer insulating zone comprising a metallic foil and ceramic coating has not been disclosed in the public literature.

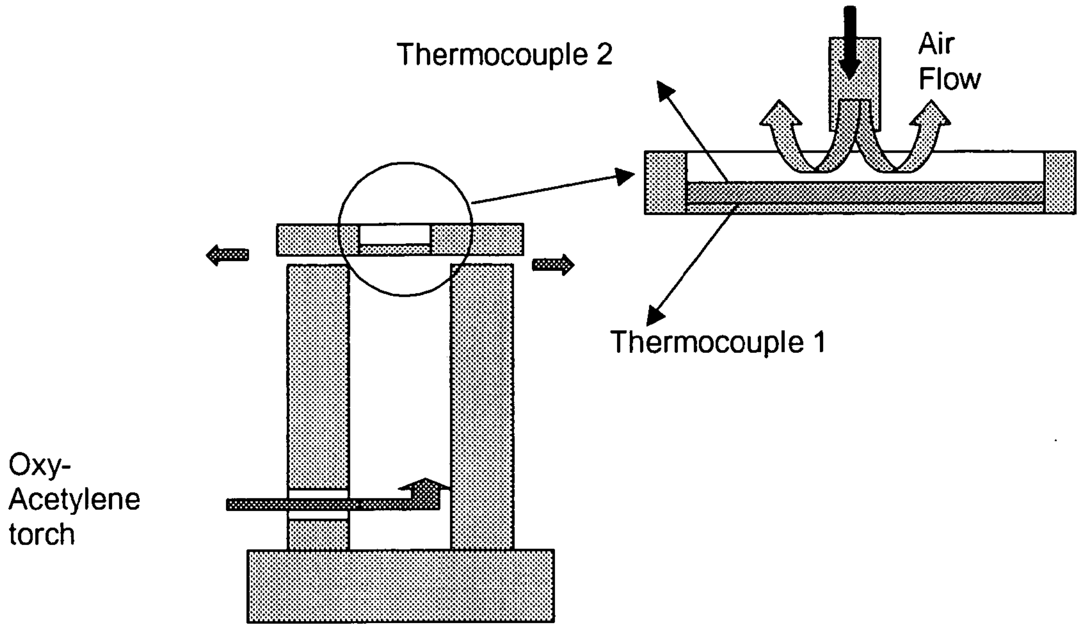
Unexpected Benefits/Advantages: Advantages of the ceramic lined metal exhaust manifold are: significant reduction in heat loss from exhaust gas into the engine compartment, more fuel efficient engine operation, and reduce catalyst warm-up time to optimum catalytic converter performance or fast light-off. In addition, reduction of under hood temperature allows selection of lower cost polymers for electrical insulation.

Appendix

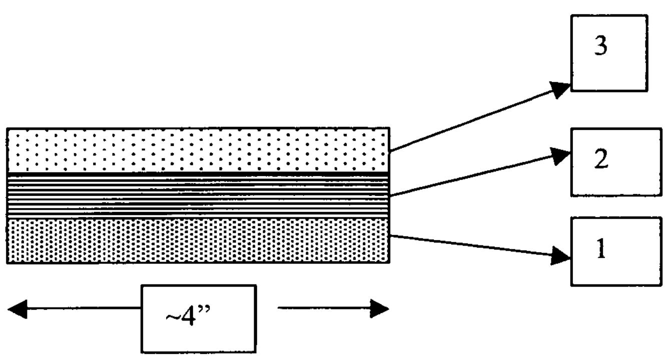
Architecture of the Manifold



High Temperature Test Set-Up



Schematic of gas-fired hot chamber. Insulation is 1" thick Fiberfrax boards.



Test Piece for High Temperature Test

WHAT IS CLAIMED IS:

1. An exhaust manifold comprising a ceramic inner layer defining an exhaust gas passageway, a composite insulation zone disposed exterior to and adjacent said inner layer, and an outer structural layer disposed exterior to said composite insulation zone, said composite insulation zone comprising at least one metallic foil layer.

2. An exhaust manifold according to claim 1, said composite insulation zone comprising a plurality of said metallic foil layers and at least one ceramic insulating layer disposed between adjacent ones of said metallic foil layers.

3. An exhaust manifold according to claim 1, said composite insulation zone comprising a plurality of said metallic foil layers and at least one substantially evacuated annular space disposed between adjacent ones of said metallic foil layers.

4. An exhaust manifold according to claim 3, said evacuated annular space being enclosed and defined by said adjacent ones of said metallic foil layers.

5. An exhaust manifold according to claim 1, said composite insulation zone comprising a plurality of said metallic foil layers and at least one microsphere layer disposed between adjacent ones of said metallic foil layers.

6. An exhaust manifold according to claim 5, said microsphere layer being a highly evacuated microsphere layer.

7. An exhaust manifold according to any one of the preceding claims, further comprising a strain isolation layer disposed between said composite insulation zone and said outer structural layer.

8. An exhaust manifold according to claim 7, said strain isolation layer being an intumescent mat.

9. An exhaust manifold according to claim 8, said intumescent mat comprising, by

weight, 20-60 percent ceramic fibers, and 35-75 percent expandable material.

10. An intumescent mat according to claim 9, said expandable material being vermiculite, perlite, or a mixture thereof.

11. An exhaust manifold according to claim 9, said intumescent mat further comprising an organic binder material effective to bind said ceramic fibers together to provide a coherent fibrous mat.

12. An exhaust manifold according to claim 8, said intumescent mat being a highly porous, compliant and resilient fibrous mat.

13. An exhaust manifold according to claim 9, said intumescent mat exhibiting the property of expanding on heating of said mat, and contracting on cooling thereof.

14. An exhaust manifold according to claim 9, said intumescent mat having a crossover temperature below which said mat exhibits the property of expanding on heating and contracting on cooling, and above which said mat no longer exhibits the property of contracting on cooling.

15. An exhaust manifold according to claim 1, wherein said inner layer is 0.05-5 mm thick.

16. An exhaust manifold according to claim 1, wherein said composite insulation zone is 1-40 mm thick.

17. An exhaust manifold according to claim 1, wherein said outer layer is 1-25 mm thick.

18. An exhaust manifold according to claim 7, said strain isolation layer being a compliant layer effective to accommodate unmatched thermal expansion between said outer structural layer and said composite insulation zone.

19. An exhaust manifold according to claim 1, wherein said inner layer comprises a catalyst effective to convert at least a portion of CO and NO_x in an exhaust gas flowing through said exhaust passageway to CO_2, and N_2 and O_2 respectively.

20. An exhaust manifold according to claim 19, wherein said catalyst has the form ABO_x and is selected from the group consisting of a) a perovskite catalyst, wherein A is a rare earth element and an alkaline earth element, and B is a transition metal element; and b) a fluorite catalyst, wherein A is a rare earth element and B is Ce or Zr.

21. An exhaust manifold according to claim 20, said catalyst being a perovskite metal oxide catalyst, wherein A is lanthanum and strontium, and B is selected from the group consisting of iron, cobalt, manganese, titanium, gallium, chromium, and nickel.

22. An exhaust manifold according to claim 21, where x is 2-5.

23. An exhaust manifold according to claim 19, said catalyst being a fluorite metal oxide catalyst, wherein A is a rare earth element, B is either Ce or Zr.

24. An exhaust manifold according to claim 23, where x is 1-4.

25. An exhaust manifold according to claim 1, further comprising a plurality of intumescent tabs provided in openings made at discrete locations through said composite insulation zone to stabilize the inner layer relative to the outer layer, and to dampen vibrational stress therebetween.

ABSTRACT OF THE DISCLOSURE

An exhaust manifold is provided having a ceramic inner layer defining an exhaust gas passageway, and a composite insulation zone that is highly thermally insulating. The manifold preferably has a metal outer structural layer to impart strength to the manifold. The composite insulation zone includes a plurality of metallic foils in alternating arrangement with layers having insulating qualities, which construction has been found to impart superior insulating properties compared to conventional exhaust manifold constructions. In the composite insulation zone, the layers having insulating qualities can be ceramic layers, evacuated spaces, microsphere layers including substantially evacuated microspheres, or a combination of these.

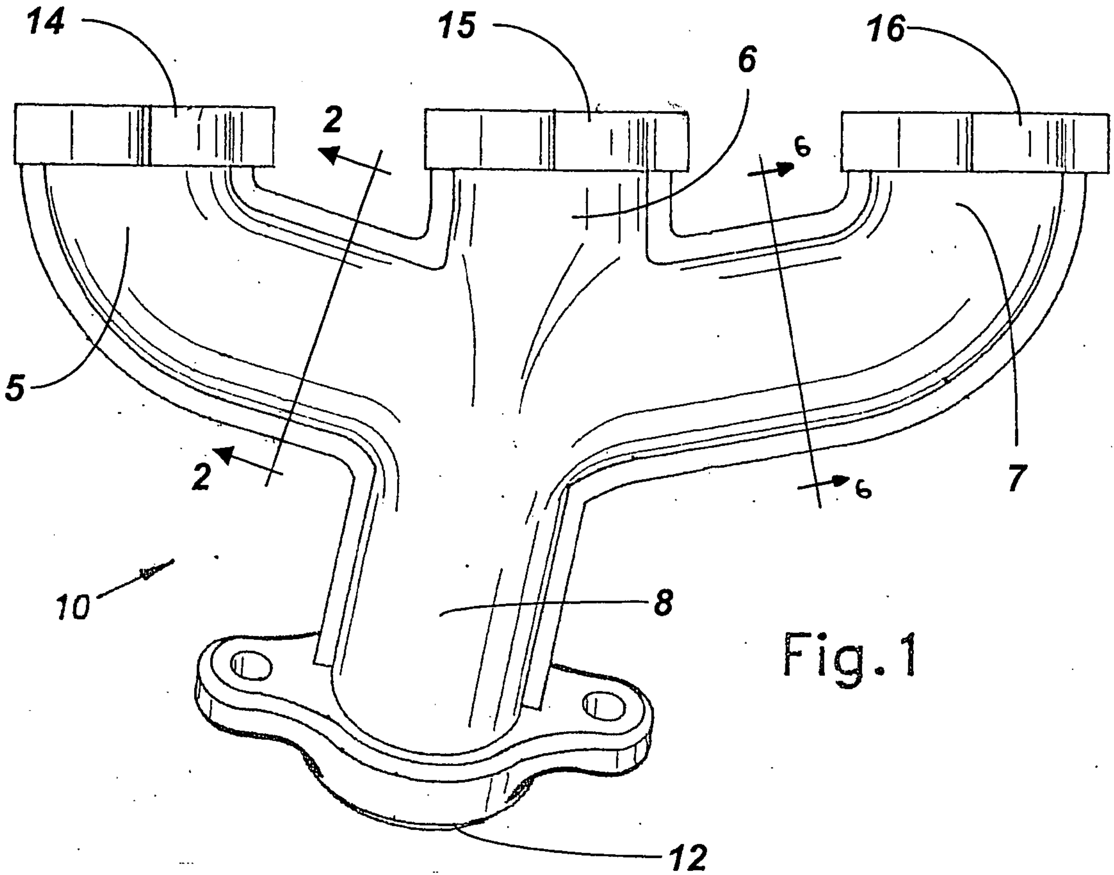


Fig. 1

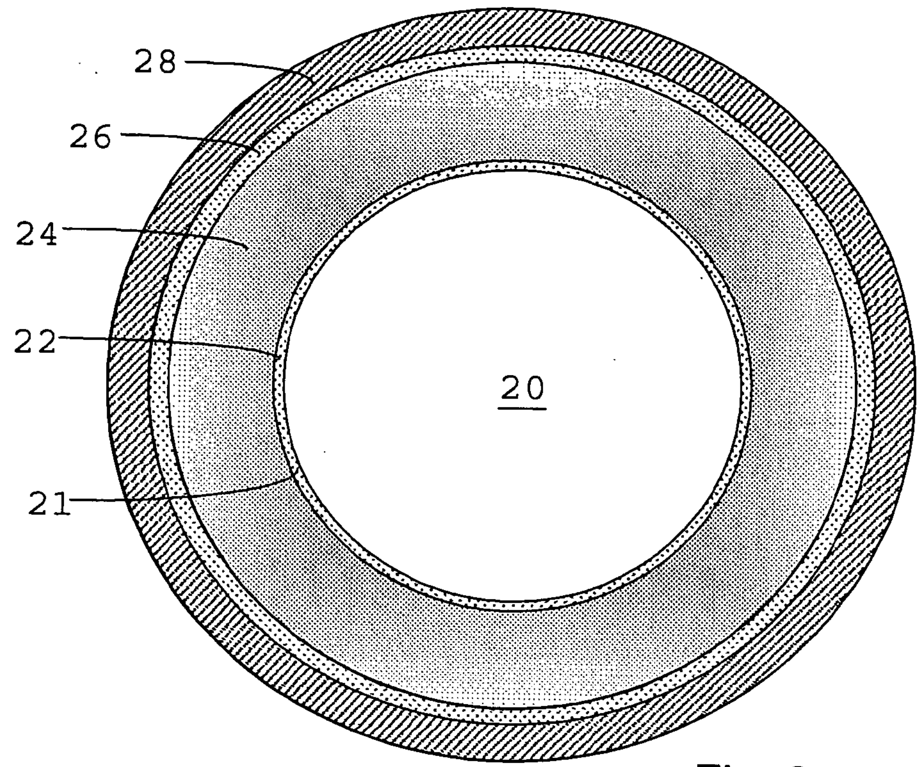


Fig. 2

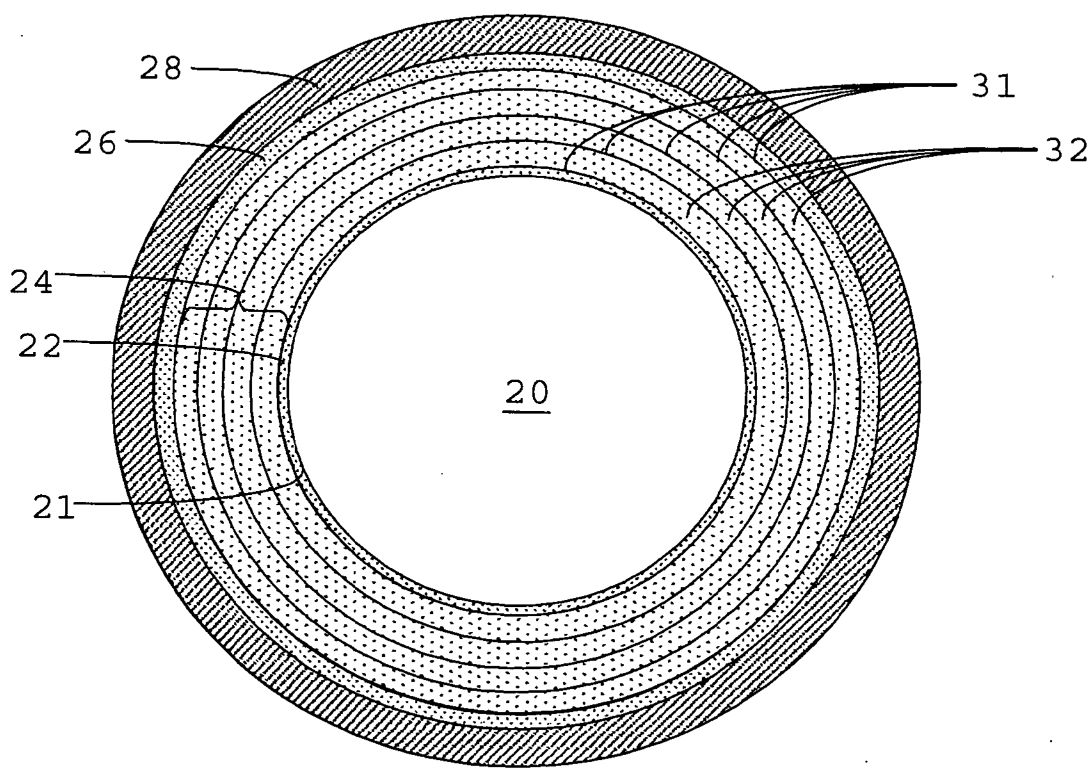


Fig. 3

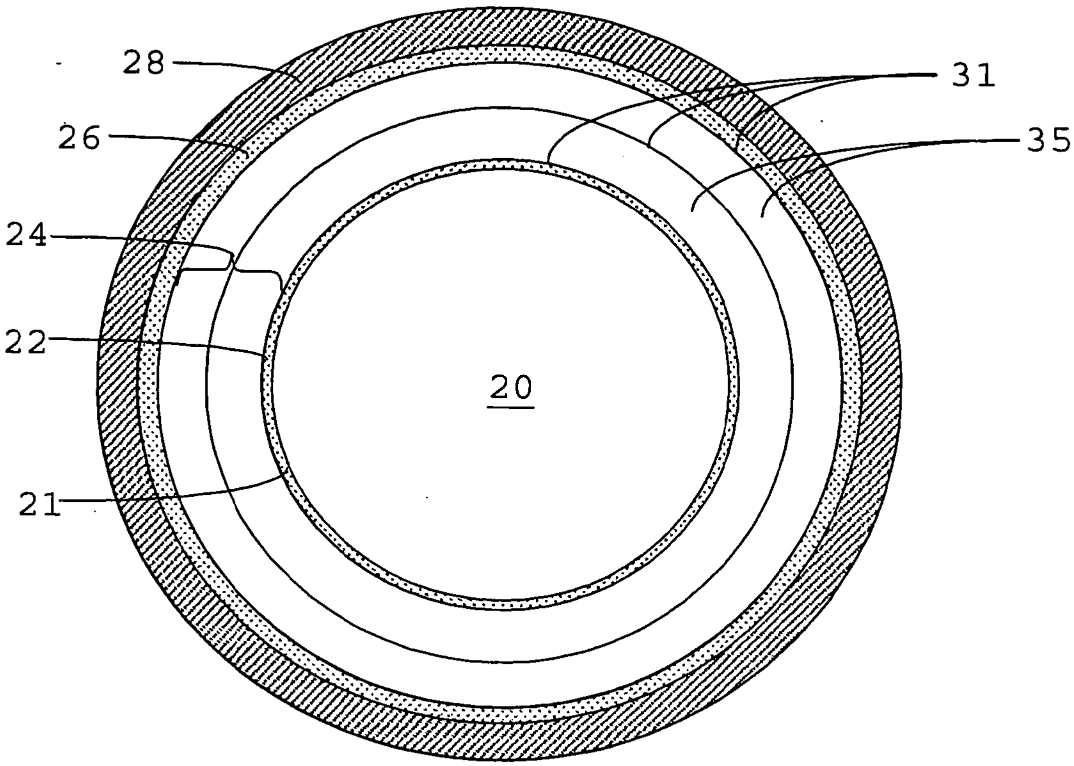


Fig. 4

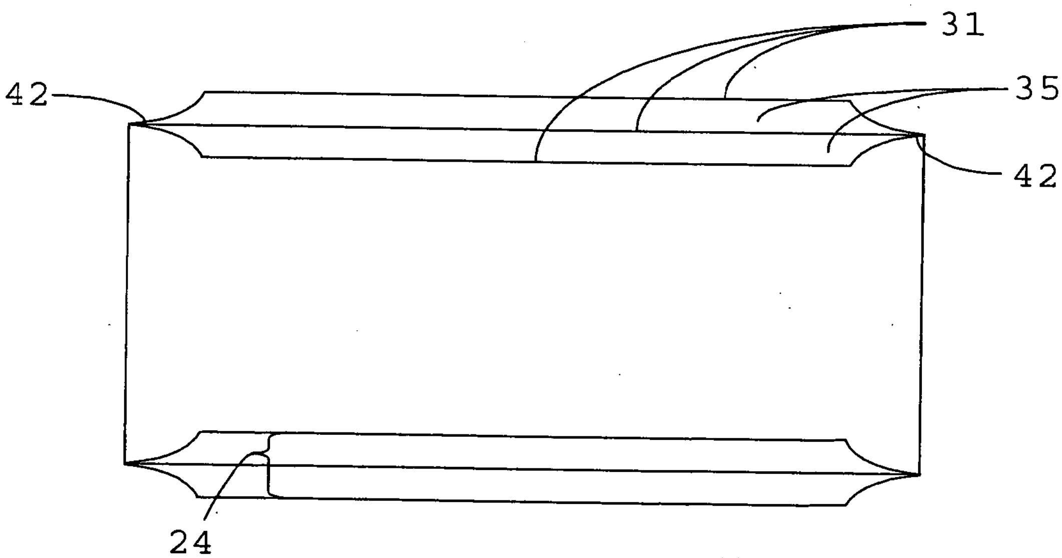


Fig. 4a

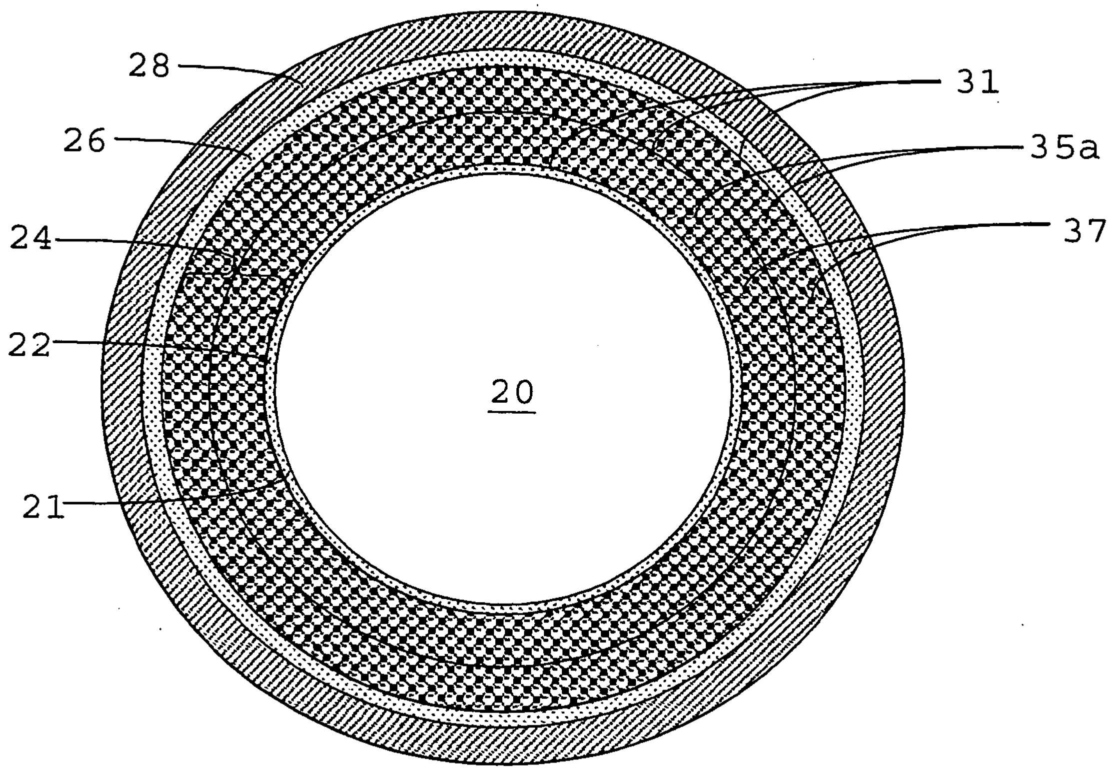


Fig. 5

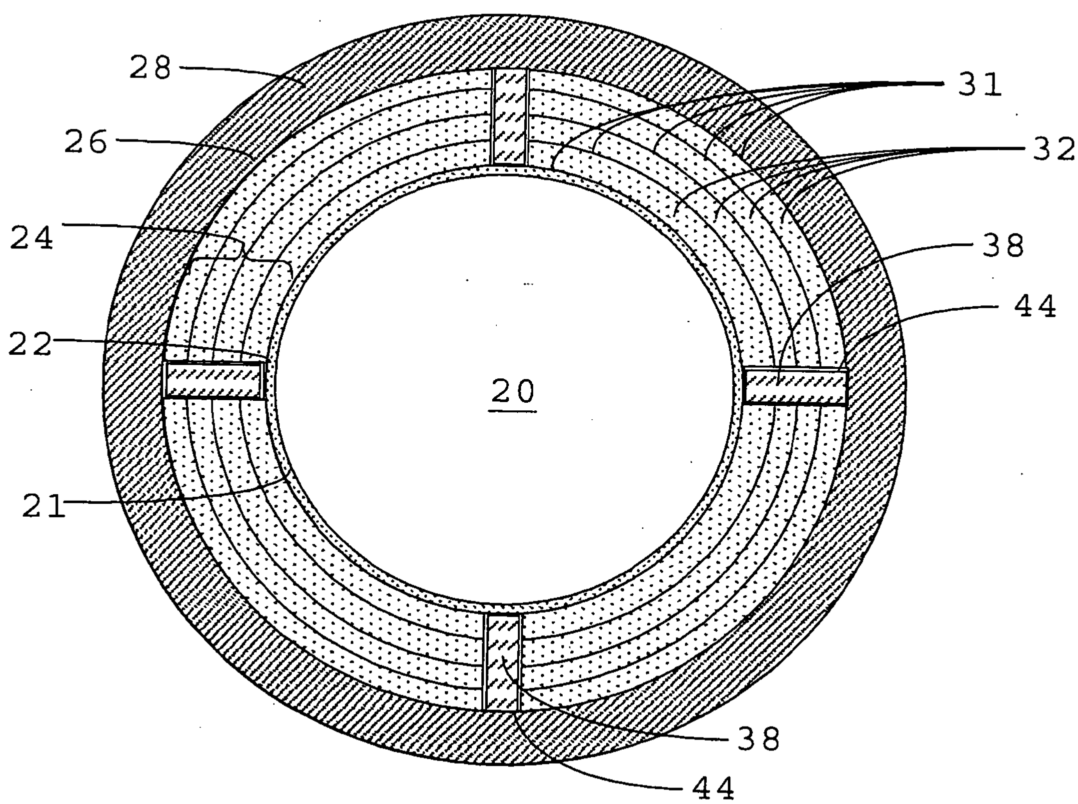


Fig. 6